

PARTICLE PHYSICS RESEARCH: *A BRIEF* INTRODUCTION

Teacher Research Internship
Fermilab – Summer 2011

...also known as ...

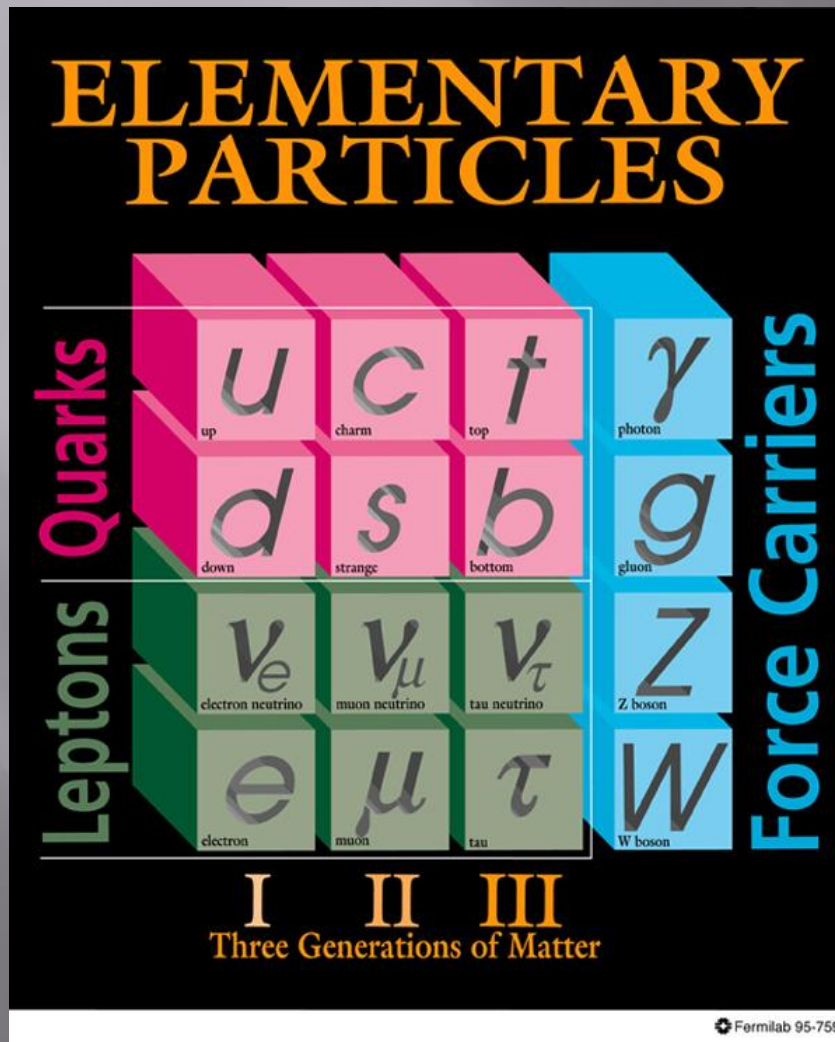
...also known as ...
a search for
tiny particles...

...also known as ...
a search for **tiny**
particles...
using large
detectors...

...also known as ...
a search for **tiny** particles...
using **large** detectors...
which generate
massive amounts
of data...

...also known as ...
a search for **tiny** particles...
using **large** detectors...
which generate **massive**
amounts of data...
in order to make
Phenomenal
discoveries!!

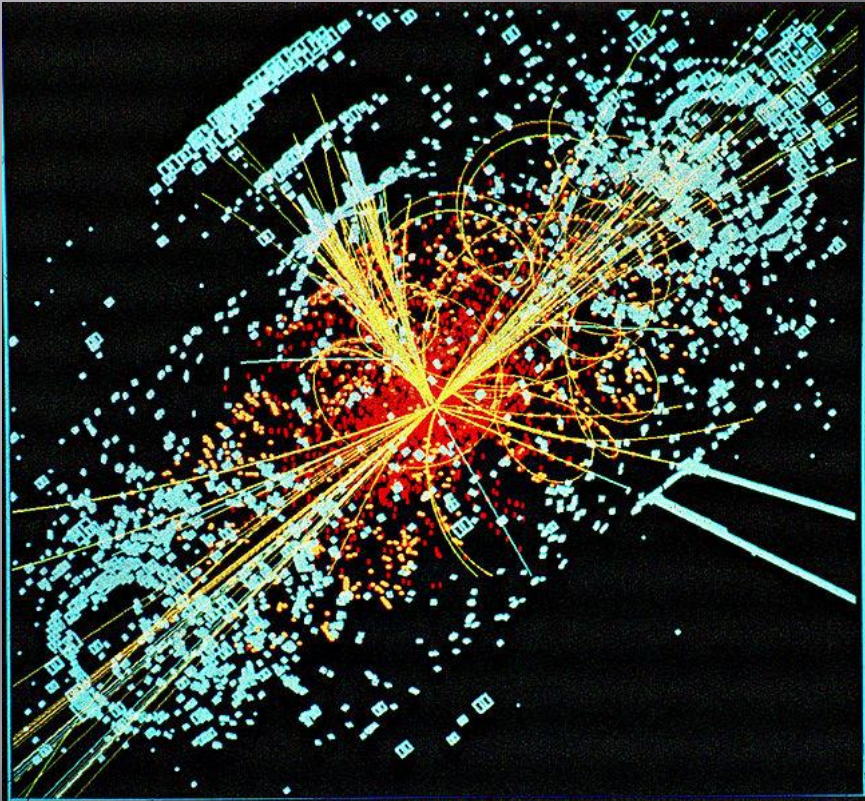
...a search for **tiny** particles...



16 Particles Observed:

- ✓ **Photon** - 1895
- ✓ **Electron** - 1897
- ✓ **Muon** - 1937
- ✓ **Electron neutrino** - 1956
- ✓ **Muon neutrino** - 1962
- ✓ **Up, Down & Strange Quarks** - 1969
- ✓ **Charm Quark** - 1974
- ✓ **Tau** - 1975
- ✓ **Bottom Quark*** - 1975
- ✓ **Gluon** - 1979
- ✓ **W & Z Bosons** - 1983
- ✓ **Top Quark*** - 1995
- ✓ **Tau Neutrino*** - 2000

...a search for **tiny** particles...

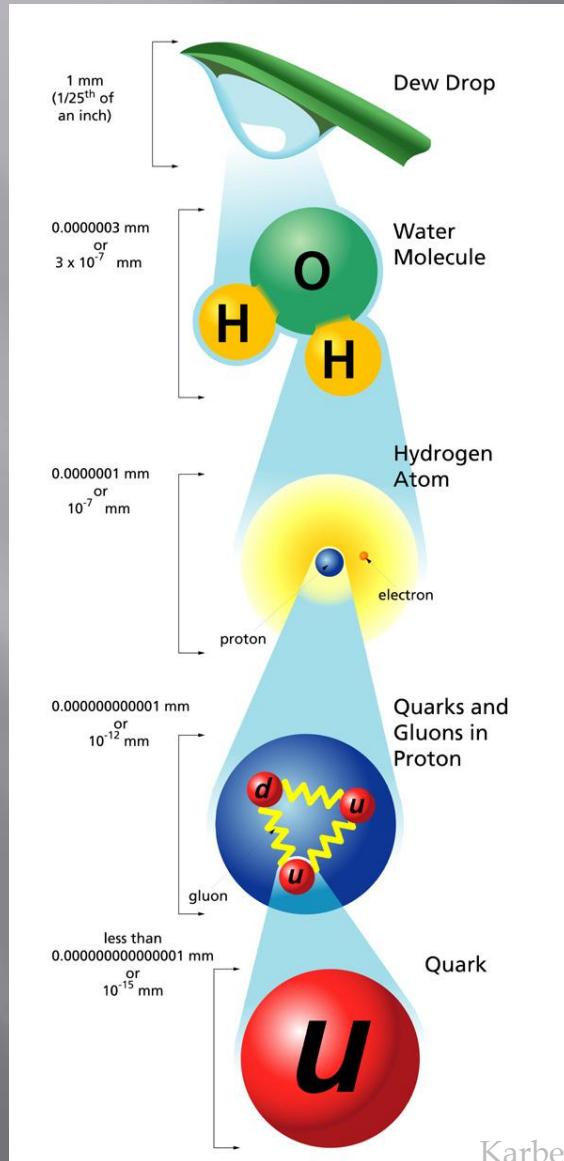


What is left to find?

Higgs Boson

- ▣ Last particle to complete SM theory
- ▣ Believed to explain how massive particles have mass, and others do not
- ▣ Search is ongoing

...a search for **tiny** particles...



How **tiny** are the particles?

- ▣ Heaviest: Z Boson 91.2 GeV = 1.6×10^{-25} kg
- ▣ Require indirect observation
- ▣ Clever detectors:
 - Silicon detectors
 - Sintilators
 - Photomultiplier Tubes
 - LOTS of Electronics!

... using large detectors...

- ▣ Accelerator Labs in US:
 - **Fermi National Accelerator Laboratory** (Batavia, IL)
 - SLAC National Accelerator Laboratory (Menlo Park, CA)
 - Jefferson Lab (Newport News, VA)
- ▣ World's Highest Energy Particle Accelerator – **Large Hadron Collider** (LHC) (Geneva, Switzerland)



... using large detectors...

Accelerator Experiments at Fermilab

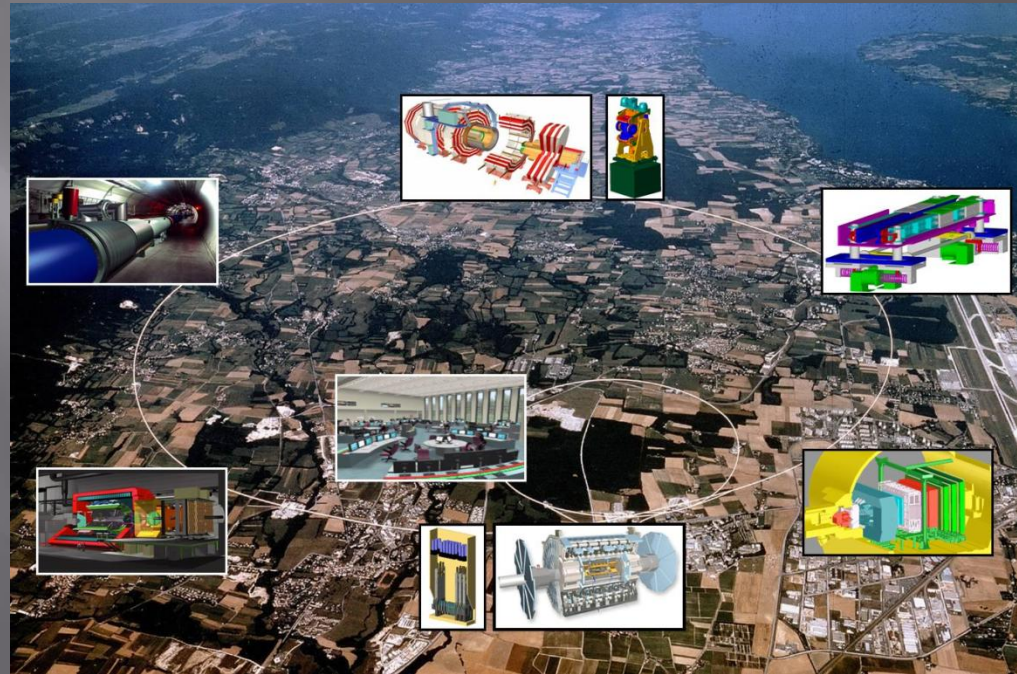
- ▣ Tevatron:
 - Proton – Antiproton collisions
 - Particles accelerated to 99.999954% speed of light
 - Beam frequency: 48,000Hz
 - 4 mile ring
- ▣ Detectors:
 - CDF
 - DZero



... using large detectors...

Large Hadron Collider

- ▣ Details:
 - Proton – Proton collisions
 - 99.9999991% speed of light
 - 7 times more energy than Tevatron
 - 16.5 mile ring
- ▣ Experiments:
 - CMS & ATLAS
 - ALICE, LHCb, LHCf, TOTEM

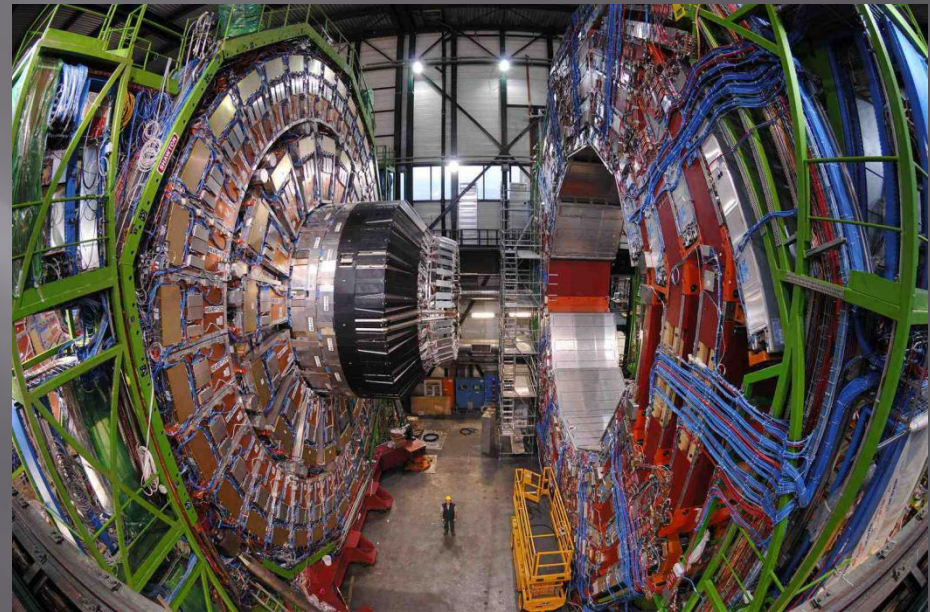


... using large detectors...

Compact Muon Solenoid

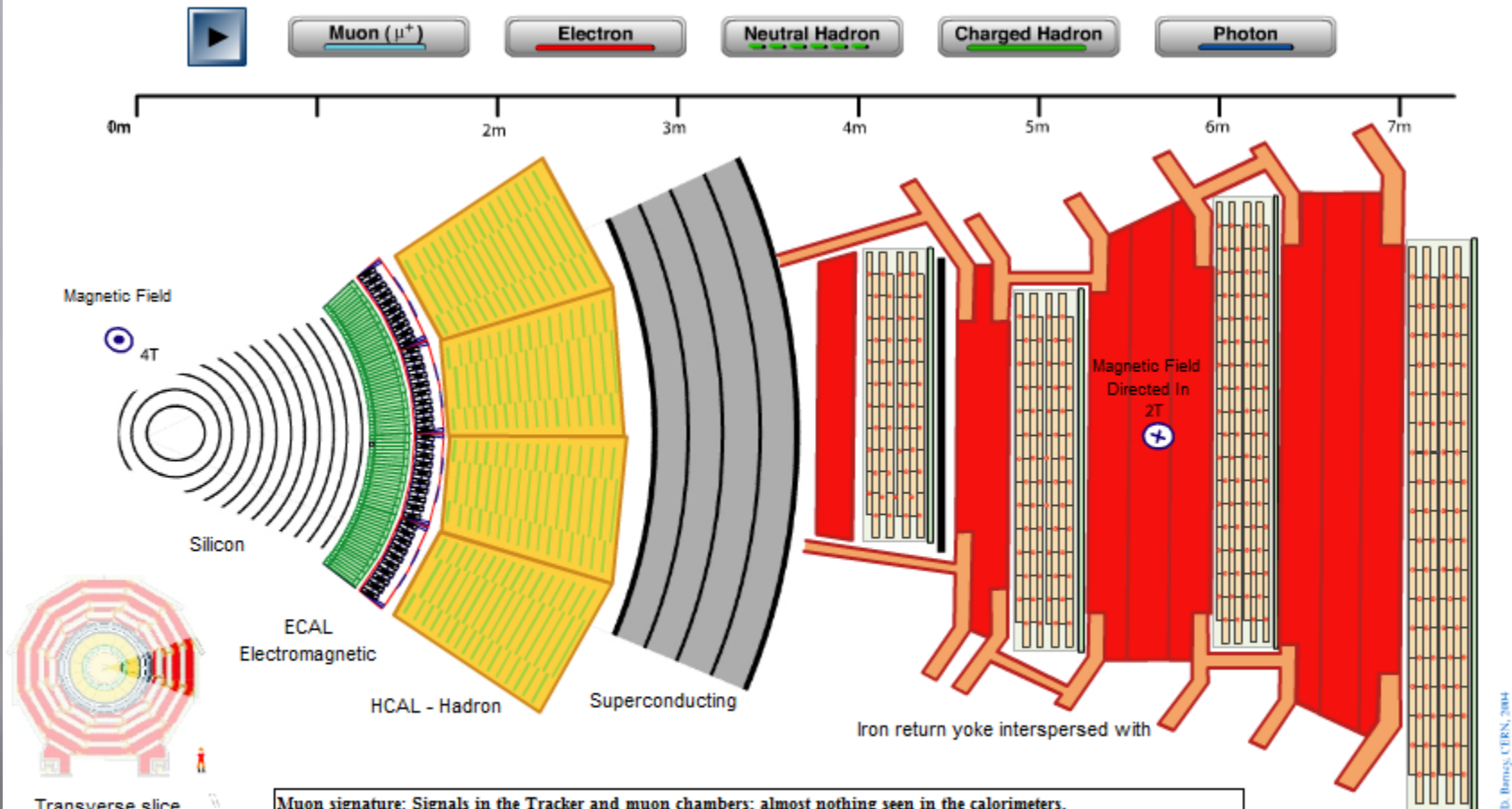
Details:

- ▣ B-Field: 4 T =
100,000 times Earth's
- ▣ 15 meters high
- ▣ 14,000 tons
- ▣ 100 meters below ground
- ▣ Electromagnets cooled to
4.6 K = - 451 degrees F



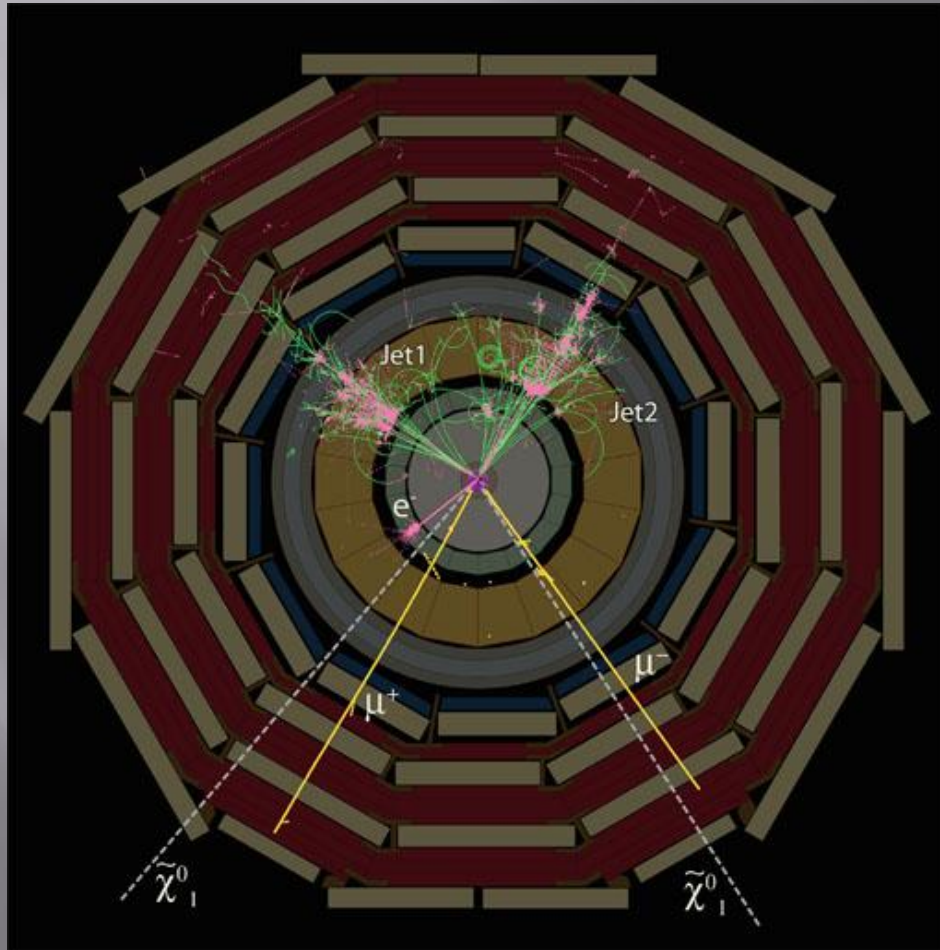
... using large detectors...

Transverse Slice of the Compact Muon Solenoid (CMS) Detector



Muon signature: Signals in the Tracker and muon chambers; almost nothing seen in the calorimeters. Muons are perhaps the easiest particles to identify in CMS: no other charged particle traverses the whole detector. Being charged, they are bent by the field in one direction inside the solenoid and in the opposite direction outside. As muons can only arise from the decay of something heavier their presence signifies that something potentially interesting has happened.

... massive amounts of data...

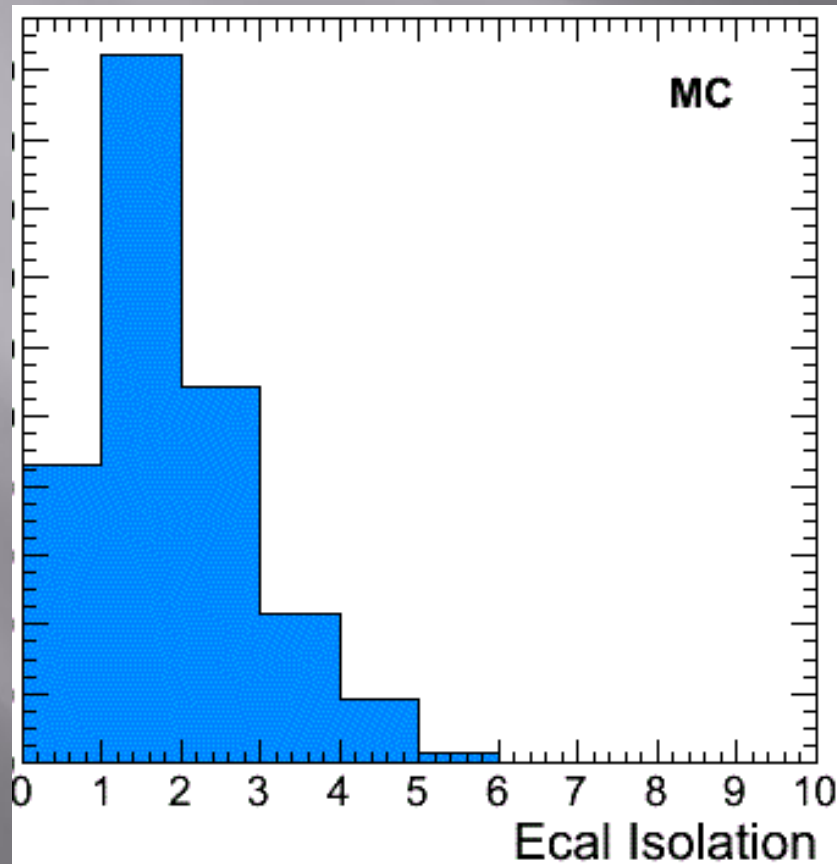


CMS Data Analysis

- ▣ **Collisions:** 40 million times per second
- ▣ **Luminosity:** over 1fb^{-1}
March - June 2011
 70×10^{12} collisions
- ▣ **Triggers:** identify interesting events
- From 1 billion to 100 per second
- ▣ **Data storage:** Tier system

... massive amounts of data...

E-Cal Isolation - Distribution

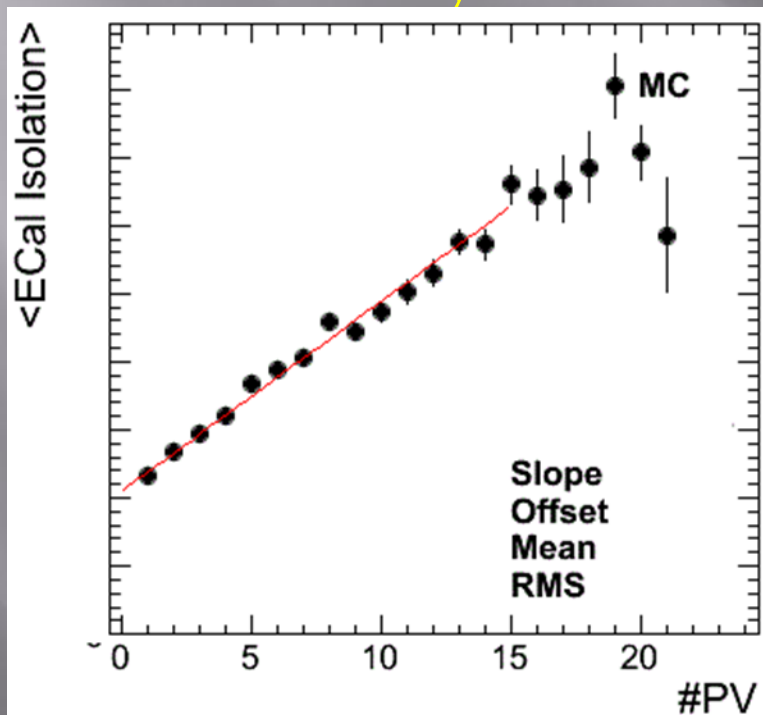


CMS Data Analysis – Photon + Jet Events

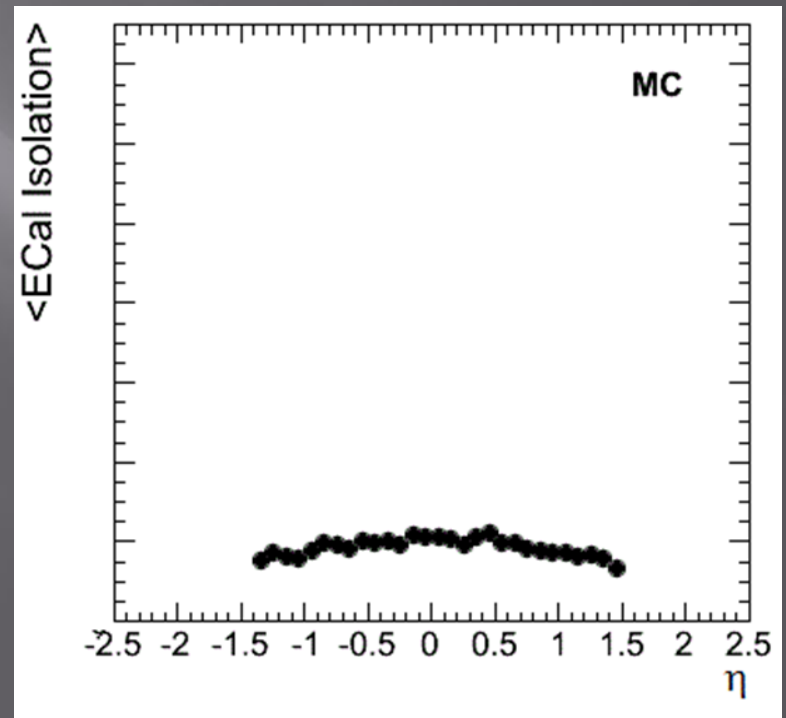
- ▣ Perform
“Sanity Checks”
- ▣ Compare data with
theoretical predictions
– Monte Carlo method

... massive amounts of data...

CMS Data Analysis – Number of Primary Vertices a.k.a “Money Plot”



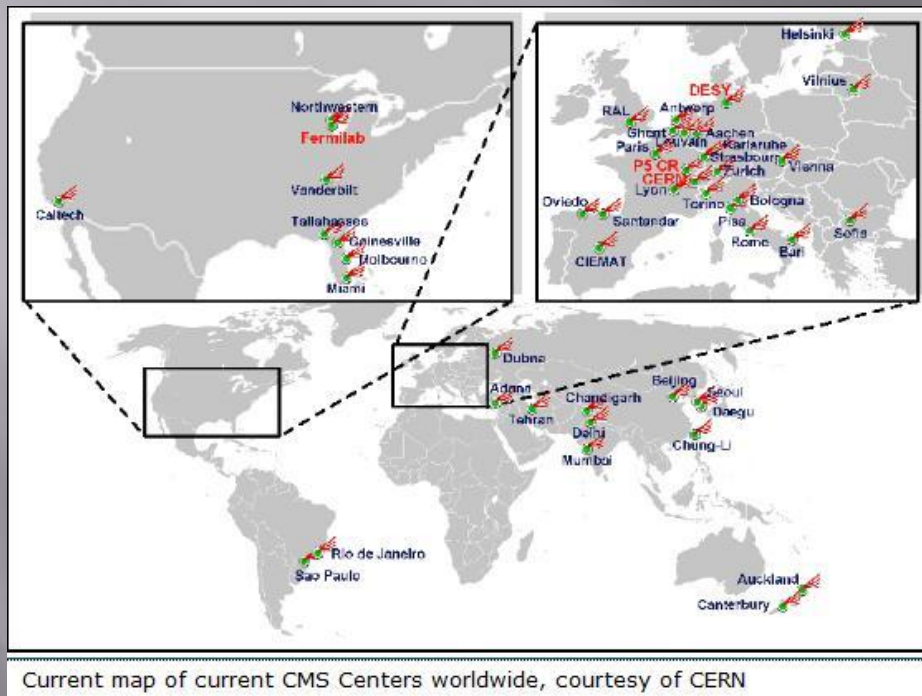
Photon + Jet Events Photon distribution in η



... massive amounts of data...

CMS Data Analysis

- ▣ Collaboration locally and internationally
- ▣ Over 3000 scientists
- ▣ Presentation of findings
 - collaboration groups
 - larger committees
 - conferences

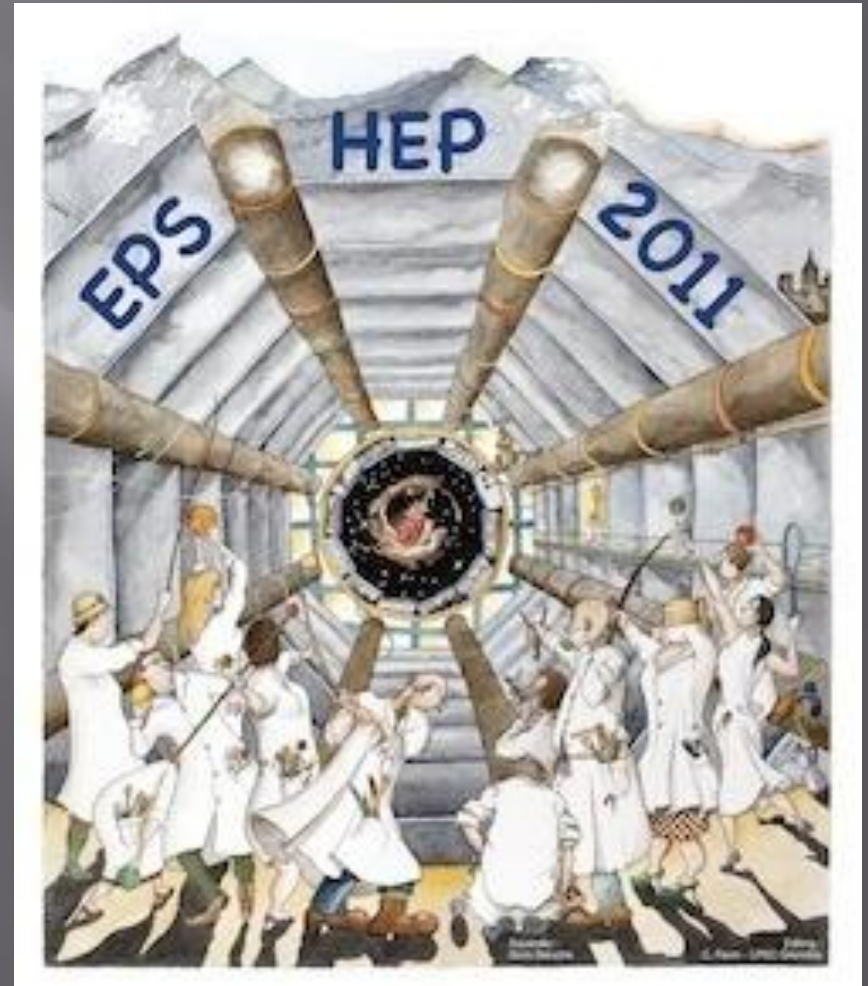


... to make Phenomenal discoveries!!

Results announced during
Summer 2011

“Higgs buzz at
summer physics
conference”

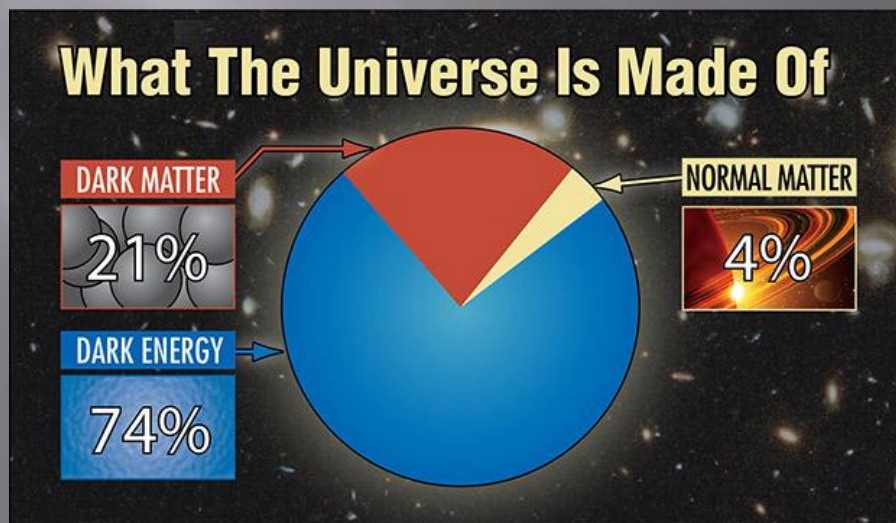
- ▣ DZero
- ▣ CDF
- ▣ CMS
- ▣ ATLAS


























... to make Phenomenal discoveries!!

Further questions...

- Dark Matter
- Dark Energy
- Anti-matter



Quarks		Anti-quarks	
			
up	down		
			
top	bottom		
			
strange	charm		
Leptons		Anti-leptons	
			
electron	electron neutrino		
			
muon	muon neutrino		
			
tau	tau neutrino		

...Many Thanks to...

- ▣ Vasundhara Chetluru for being a great mentor and resource
- ▣ Harry Cheung & Bjoern Penning and the TRAC program for providing such a great opportunity for learning and research
- ▣ My fellow interns for sharing their experiences and resources

Run 494 Event 257 FILE DSRDAT: SBB494

28-OCT-1985 16:10

